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Resilient DC LV communities – UPB demonstrator

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SUMMARY

Nowadays the world of systems, and especially critical infrastructures, is more and more interconnected. The electrical power supply forms the backbone of this interconnected world. Extreme weather is proved to play a major role in the cause of power outages (about 80% of the cases according to a report of Climate Central's analysis of 28 years of power outage data in the USA [1]). A study commissioned in 2012 by the Congress of USA concluded that the estimated cost from storm-related outages to the U.S. economy is between $20 billion and $55 billion annually [2]. Another case study in Europe concerning the Swedish power critical infrastructure estimated an economic loss on the electric power service alone to be around 3 billion euros due to a heavy storm in 2005 [3]. Both latter studies concluded that power delivery systems are the most vulnerable to weather events. Thus, improving the overall efficiency and condition of the low voltage part of the power system can only serve to improve its resiliency and help a fast recovery from outages (weather-related or not).

Low voltage microgrids that integrate storage technologies and renewables are cited as viable options to address resilience challenges faced by the power delivery systems in extreme weather events and even under man-made threats. They could be distributed, resilient by design cells, in a smart power system architecture. Several problems in AC microgrids, such as synchronization of distributed generators, inrush currents (due to transformers, induction motors or induction generators), or three-phase unbalance (due to single-phase loads or single-phase PV generators) lead to research and development interest in solutions for low voltage DC microgrids.

The MicroDERLab Research Group from UPB is involved in several European Commission Funded Projects that target to demonstrate the functionality and operability of such systems. They target several complementary features to be tested and validated such as:

- modelling, planning, integration, operation and evaluation of distributed Energy Storage Systems (Storage4Grid);
- to evaluate and estimate the technical and business feasibility and sustainability of MV and LV scenarios where storage solutions and EV charging solutions are installed (Storage4Grid)

- integration of a Smart Energy Platform capable of supporting business models of different Smart Energy actors using smart sensors/monitoring devices, aggregation of measurement data from different sources to support future innovative services (FISMEP);
- active power management of energy consumption in prosumers' world (RESERVE);
- real-time control of the electrical network enabled by innovative 5G based ICT (RESERVE);
- demand response schemes and flexibility of the local market – i.e. new business models for aggregators and ESCOs (NobelGrid);
- analysis of novel methods for management and control of multiple LV DC microgrids operating on a specific territory; the small cluster of DC microgrids operate in a cooperative manner to achieve a high level of independence and resilience (DCNextEvE).

Thus, a demonstrator consisting of two interconnected DC low voltage microgrids is in the process to be made functional to serve the experimental assessments of several work packages and tasks in these projects. The architecture needs to be modular, flexible and adaptive enough to serve these purposes, as well as future related projects.

The poster will expand on the assumptions and technical characteristics of the proposed architecture with the main purpose to serve as a resilient small community of microgrids, while serving the above-mentioned objectives. Furthermore, the results of simulations on the functionality of a distributed and adaptive energy management system to be tested on this demonstrator will be summarized.

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Resilient DC LV communities – UPB demonstrator

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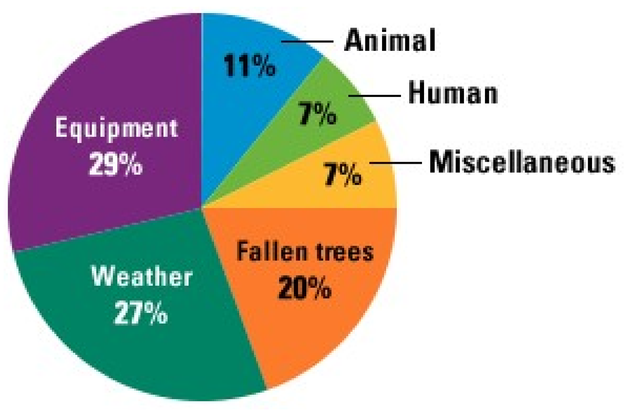
Abstract

This work presents the architecture and operational features of a demonstrator developed at the premises of MicroDERLab Research Group at UPB that consists of two interconnected DC low voltage microgrids aiming to serve several research projects that focus on resilient DC LV communities. The architecture of the demonstrator uses a case-driven approach to validate and demonstrate the toolkits to be developed. Concretely, the demonstrator aims to facilitate the experimental assessments of several applications from monitoring and active power management of energy consumption in prosumers' world, to aggregation of measurement data for modelling, planning, integration, operation and evaluation of distributed Energy Storage Systems. One of the major innovation of the proposed architecture consists in the extension of the functionality of the Unbundled Smart Meter (USM), the so called SMX side that processes all the information coming from the micro-controller of the energy router (ER). Simulated results of a distributed and adaptive energy management system to be tested on this demonstrator are also presented, while briefing a number of use-cases in line with several business models that led us to this design.

Background

Extreme weather is proved to play a major role in the cause of power outages (about 80% of the cases according to a report of Climate Central's analysis of 28 years of power outage data in the USA [1]). A study commissioned in 2012 by the Congress of USA concluded that the estimated cost from storm-related outages to the U.S. economy is between $20 billion and $55 billion annually [2]. Another case study in Europe concerning the Swedish power critical infrastructure estimated an economic loss on the electric power service alone to be around 3 billion euros due to a heavy storm in 2005 [3]. Both latter studies concluded that power delivery systems are the most vulnerable to weather events. Thus, improving the overall efficiency and condition of the low voltage part of the power system can only serve to improve its resiliency and help a fast recovery from outages (weather-related or not).



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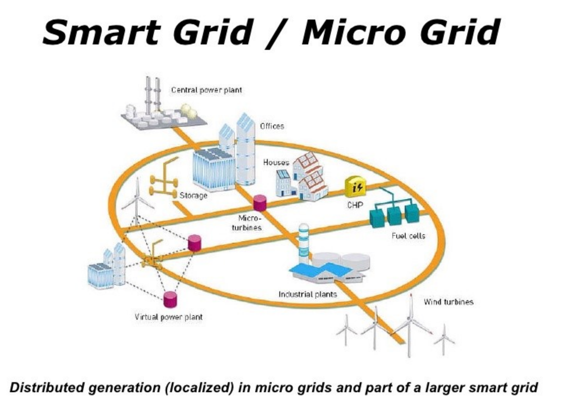


Source: www.resilience.org

Business and resilience assumptions on the design of the system

The proposed architecture is based on the technical philosophy that the new prosumer at the LV side of the grid shall be seen by the DSO as a "consumer-only" entity from DSO point of view [4]. Storage plays a key role in migrating the prosumer's behavior back to the design assumptions of the legacy power distribution system.

Key features of the resilient by design microgrid's architecture:

- almost risk-free RoI over the lifetime of the system;
- increased self-consumption of local generation, close to unity factor;
- increased resilience of the microgrid in case of grid outages;
- easy scaling-up potential at community level ("plug-and-play" expansion plan);
- decoupling the need for synchronization (grace to the DC bus);
- smooth connection to the main grid with no need for planning or changes in the current SoA architectures & operation of DSO's grids.

Operation use-cases for resilience

Use case 1: a disturbance on the local power production from PVs or on the loads side allows the MG(s) to still work based on the grid former and grid balancer reactions (ER role) power set points for the DSO remain unchanged ("non-undisturbed" DSO).

Use case 2: whenever a disturbance occurs on the DSO side, which may change the scheduled power to be provided by the DSO to the MG, the internal balancing mechanism of the MG is able to compensate it using the same mechanisms (battery/storage plus distributed low-level control).

e.g. decrease of 25% from the requested/scheduled amount.

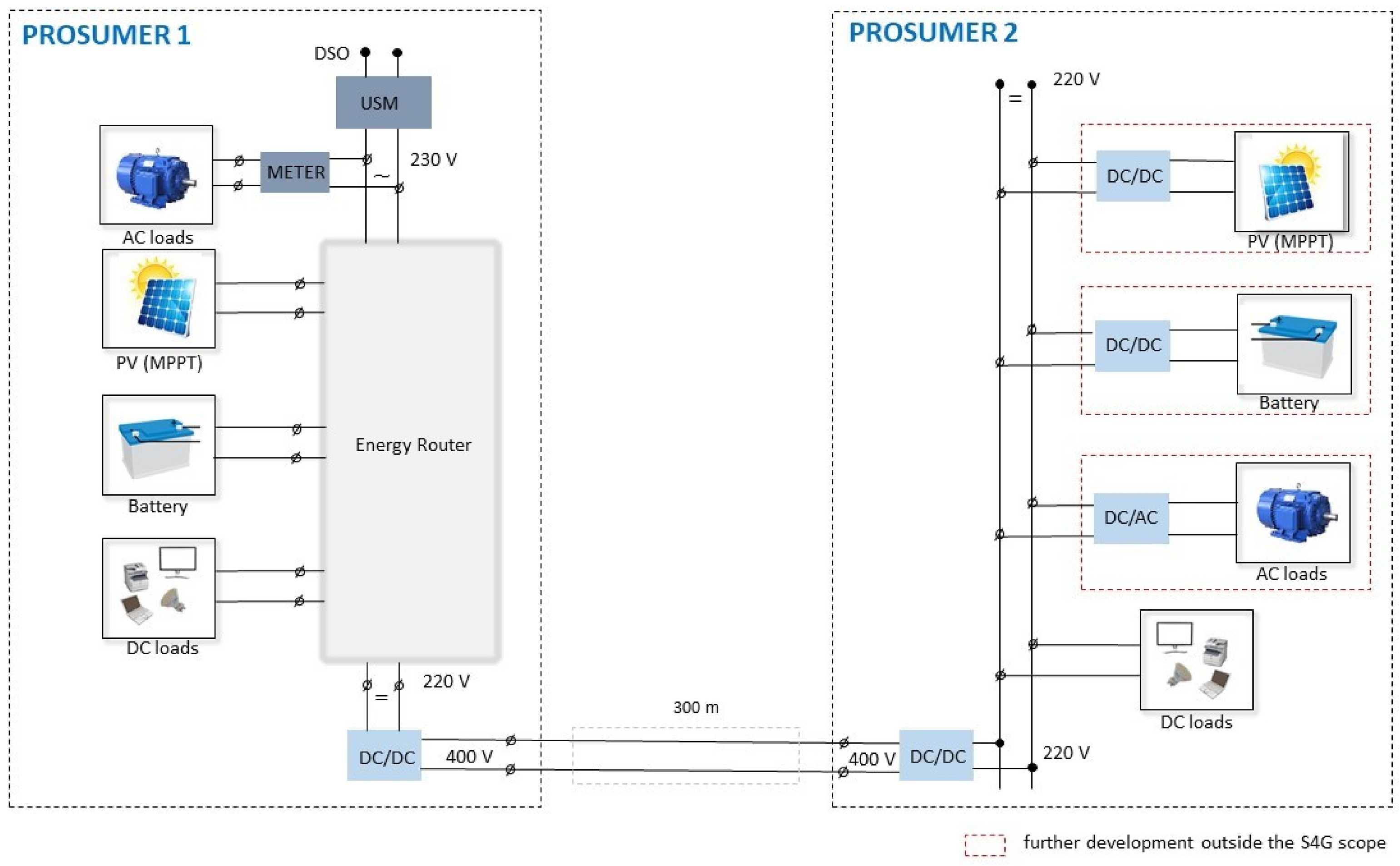
Use case 3: an extension of the use case 2 where there is a total loss of the scheduled power to be provided by the grid (DSO).

USM role

The proposed architecture place a major innovative role to the Unbundled Smart Meter (USM). To be noted that the information facilitating the microgrid control is mediated by the USM where smart meter functionalities are adequately grouped in two separate (unbundled) components:

a) one for metrological / billing purposes, handling "hard real-time" function, and called the Smart Metrology Meter (SMM); usually SMM is the already exiting smart meter.

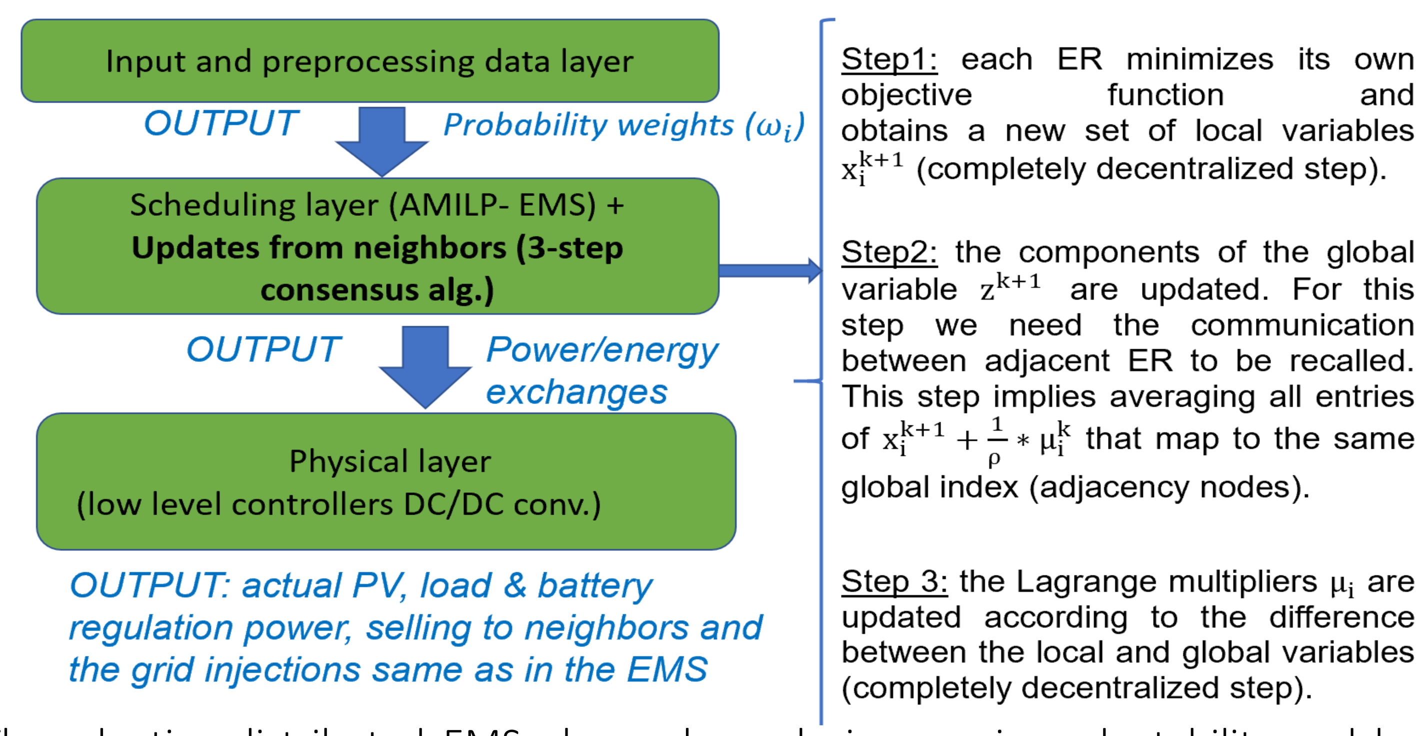
b) one Smart Meter eXtension (SMX) providing the flexibility needed for new functionality



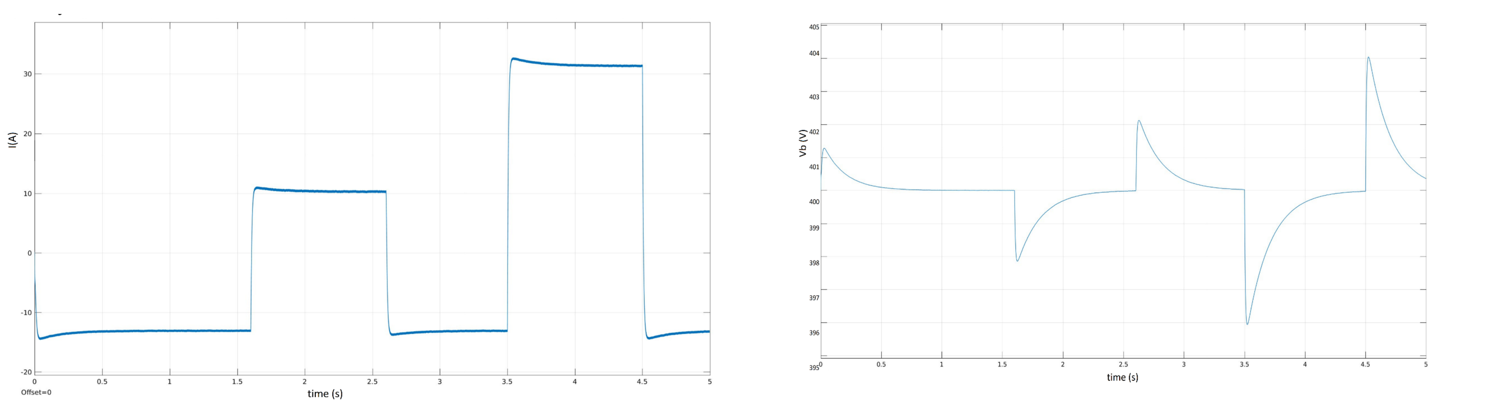
to be deployed during the meter lifetime and to support the future evolution of the smart grid and energy services. The SMX is a Linux machine, able to read from the SMM all relevant instrumentation values (using DLMS protocol) and stores data in a text file, to be later processed/used, including for developing a local load profile [5].

Energy management system for resilient communities

Formulation based on an adaptive distributed general consensus problem. The solution makes use of a smart metering infrastructure with minimum requirements for communication between the operational nodes. The algorithmic implementation is based on a 3-steps general consensus formulation, summarized below [6].



The adaptive distributed EMS plays a key role in ensuring adaptability and learning capabilities using a prediction and learning module for pre-processing of information.



BESS: current and voltage waveforms

Simulation scenario is as follows: @t=0 – normal/scheduled operation to supply only Load1; @t=1.6 s -> connect Load2; @t=2.6 s Load2 is disconnected due to internal disturbance in the MG. Load2 is 25% of Load1 + Load2; @t=3.5 the scheduled power intake from the grid is disconnected (disturbance in the grid) & @t=4.5 s, the power infeed (from the grid) is restored to the scheduled value.

Conclusions

This work elaborated on a number of design and operational use-cases for a Lab/Campus scale demonstrator of DC LV power distribution. The design paradigm, features and assumptions are analyzed following a set of features that characterize resilient systems.

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